

conveyed to distant parts of the field by a system somewhat similar to the dashes and dots of the Morse telegraphic code." The Nez Percés are described as a particularly fine race and well behaved. Their women are very industrious, and when not engaged in carrying wood and water, &c., "are generally hard at work in the manufacture of beaded mocassins, gauntlets, and Indian doll babies . . . The little boys, too, reap quite a harvest by displaying their skill with the bow and arrow." One of the most curious institutions of the tribe is a primitive description of Turkish bath. "The Missouri River runs close by their encampment, and on the bank of the river they have built what has the appearance of a gigantic ant-hill; in shape it is similar to a small Esquimaux hut, about six feet in diameter and two or three feet high. There is an aperture on one side just large enough for a man to get through, and in the interior there is just sufficient room for him to lie in a cramped position. They first build a fire outside in which they heat limestones until almost red-hot. They then shovel them into the hut and pour water on them so as to produce a dense vapour, after which they quickly rake the stones on, crawl in through the entrance hole which they cover up with a blanket, and lie there until the perspiration streams from every pore, when they come outside and plunge into the Missouri River and swim to the nearest sand-bank."

THE additions to the Zoological Society's Gardens during the past week include a Mona Monkey (*Cercopithecus mona*) from West Africa, presented by the Rev. W. N. Ripley; a Macaque Monkey (*Macacus cynomolgus*) from India, presented by the Rev. E. L. Marrett; a Cape Zorilla (*Ictonyx zorilla*) from West Africa, presented by Mr. Calman; a Laughing Kingfisher (*Dacelo gigantea*) from Australia, presented by Mr. Delves L. Broughton; a Red-beaked Weaver-bird (*Quelea sanguinirostris*) from West Africa, presented by Mr. W. H. Simmonds; a Passerine Owl (*Glaucidium passerinum*), European, presented by Miss Turner; a Sumatran Rhinoceros (*Rhinoceros sumatrensis*) from Malacca, an Anubis Baboon (*Cynocephalus anubis*), a Macaque Monkey (*Macacus cynomolgus*), a Bonnet Monkey (*Macacus radiatus*) from India, a Kinkajou (*Cercopithecus caudivolutus*) from South America, deposited; a Chinchilla (*Chinchilla lanigera*), born in the Gardens.

CYON'S RESEARCHES ON THE EAR.

I.

THIS able and elaborate thesis, presented by Dr. de Cyon to the Medical Faculty of Paris, contains a further contribution of facts and speculations in reference to the function of the semicircular canals of the internal ear, a subject upon which, as Professor of Physiology in St. Petersburg, he had previously published an important and interesting paper.

As a knowledge of the form and position of these organs is absolutely necessary to enable the reader to follow a discussion of the theories as to their use, we shall preface this notice of Dr. de Cyon's thesis with a short anatomical statement.

The system of semicircular canals, which exists in the internal ear of all vertebrates, while differing greatly in size in different animals, is so nearly the same in general arrangement, that a description of it as found in man will be sufficient for our present purpose.

These organs are lodged in a bony cavity continuous with the cochlea which contains the organ of hearing. The vestibule is an irregular rounded chamber. In its walls are five openings leading to the semicircular canals. These are tunnels in the bone having an elliptical or circular section, and opening at each end into the vestibule. The central line or axis of each canal lies nearly in one plane (which we may call the plane of the canal), and is approximately an arc of a circle. At one end of each canal there is an enlargement called the ampulla. The diagram (Fig. 1) represents a section through the axis of one of the canals.

The planes of the three canals are very nearly at right angles

to one another. The canals are named from their position—the horizontal, the superior, and the posterior; the two latter unite at their non-ampullary ends before joining the vestibule, so that

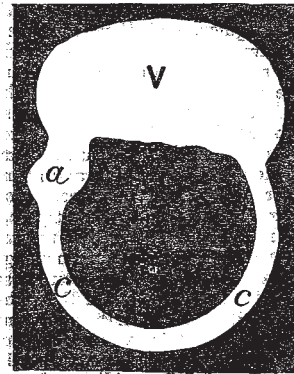


Fig. 1.

Section of bony labyrinth showing vestibule and one of the semi-circular canals. V, vestibule; CC, canal; a, ampulla.

there are five, and not six, openings into the vestibule—three ampullary, one for each canal, and two non-ampullary, one for the horizontal and one common to the superior and posterior canals.

The plane of the horizontal canal is nearly horizontal in the ordinary position of the head in all animals,¹ and is always at right angles to the mesial plane; the planes of the other two canals make nearly equal angles with the mesial plane. These relations are indicated diagrammatically in the accompanying sketch (Fig. 2), from which, to prevent confusion, the vestibule has been omitted.

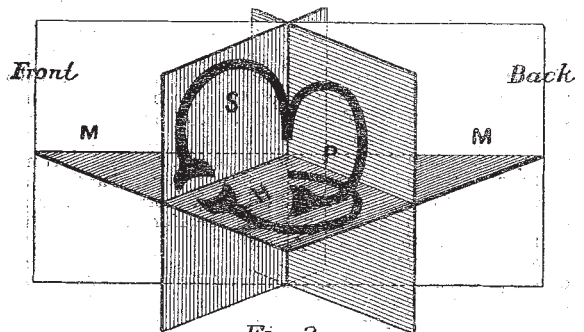


Fig. 2.

Diagram showing the relations of the planes of the three semi-circular canals of the left ear to each other and to the mesial plane. M, M, mesial plane; S, P, H, the planes of the superior, posterior, and horizontal canals respectively.

In the bony labyrinth just described is inclosed a membranous labyrinth, similar in form, and consisting of the utricle, lodged in the vestibule, and of three membranous semicircular canals, each furnished with a membranous ampulla. The membranous labyrinth does not fit tight into its bony case—the utricle is much smaller than the vestibule (which contains, besides, other organs connected with the cochlea), and the diameter of the membranous canals is not more than one-fifth of that of the osseous canals. In the ampullæ the difference is not nearly so great; here there is only a narrow space between the bone and the membrane. The entire cavity is thus divided into two spaces, one within and one around the membranous labyrinth; each is filled with a liquid named the endolymph and the perilymph respectively. The external space contains, in addition to the perilymph, connective tissue attaching more or less firmly the membranous canals to the periosteum, and the blood-vessels and nerves which supply the membranous labyrinth. The nerves are distributed to a spot called the *macula acustica*, in the utricle,

¹ Recherches expérimentales sur les Fonctions des Canaux semi-circulaires et sur leur Rôle dans la Formation de la Notion de l'Espace. Par Elie de Cyon, M.D., &c., Lauréat de l'Institut de France.

² In man the plane of the horizontal canal slopes somewhat downwards and backwards, so that it becomes horizontal when the head is slightly bent forwards.

and to a crescent-shaped ridge, the *crista acustica*, near the middle of each ampulla. The nerves in each case end in hair cells, the hairs of which project into the endolymph. These nerves are derived from the vestibular branch of the so-called auditory nerve, or *portio mollis* of the seventh pair.

The remarkably regular, and, if we may use the expression, purpose-like arrangement of these organs must strike every one, and the mind naturally searches for the use of this curious geometrical apparatus. A theory long held, and not yet wholly abandoned, to which indeed Dr. de Cyon seems to attach some value, connects it with the perception of the *direction* of sound. The idea is not unnatural, and is obviously derived from the nearness of the apparatus to the organ of hearing and from the relation of its form to the three dimensions of space. No explanation has ever been given *how* it can serve this purpose, and a sufficient proof that it does not do so is supplied by the fact—easily tested by any one—that we have no means of knowing the direction of sound except by two or more simultaneous or successive observations. If a sound is heard louder in the right ear than in the left we conclude that it comes from the right, and by turning the head round we quickly obtain a sufficient number of observations to enable us to judge of the exact direction. If a sudden abrupt noise is made at a point equidistant from the two ears, we do not know its position unless we *see* what produces it. This theory may therefore be at once dismissed.

The first scientific inquiry into the function of the semicircular canals was made by Flourens in 1828. His experiments were conducted with an amount of care and the results described with a degree of accuracy and clearness not surpassed by any recent investigator. He observed that the section of a membranous canal was always followed by movements of the head, or even of the body of the animal *in the direction of the divided canal*; in other words, by oscillatory movements of rotation about an axis at right angles to the plane of the divided canal.

Flourens has been followed by various observers, Harless, Czermak, Brown-Sequard, Vulpian, and Löwenberg, who have confirmed the results above described, and referred them either to disturbances of hearing or to injury of the cerebellum.

An entirely new step was taken in 1870 by Prof. Goltz. Flourens had already hinted that the semicircular canals are concerned in the co-ordination of movements, but Goltz first devised a physical theory to explain how they act in this way. This theory may be called the static theory, and is, shortly stated, as follows:—We may suppose that the terminations of the nerves in the ampullæ are stimulated by pressure or by stretching, as is the case with the nerves of the skin. The endolymph contained in the canals necessarily presses most upon that part of the wall of the cavity which is situated at the lowest point, and each position of the head will correspond to a particular distribution of pressure, and therefore to a particular form of nerve stimulation; we have thus a special sensation corresponding to each position of the head. That a knowledge of the position of the head and the power of regulating it is necessary for the preservation of the equilibrium of the body, was proved by Goltz by a very ingenious experiment. He fixed the head of a pigeon in an unnatural position by attaching its occiput to its breast, so that its beak was turned up and the vertex looked forward. He found that the animal so treated walked with great difficulty, and was quite unable to fly, and exhibited many of the phenomena observable in animals whose semicircular canals had been cut or destroyed.

The next investigations of importance as to the function of these organs are those of Prof. De Cyon in 1872. He repeated with great experimental skill, and with ingeniously-contrived modifications, the operations performed by Flourens and by Goltz, obtained the same results, and, guided by his medical observations on diseases accompanied by loss of equilibrium, formulated his theory as follows:—The semicircular canals give us a series of unconscious sensations as to the position of our heads in space; each canal has a strictly determined relation to one of the three dimensions of space; the loss of equilibrium and the other disturbances of locomotion caused by the section of the canals are solely due to the disorder of these sensations.

Before considering the next step in the development of the theory we must go back and examine the experiments on vertigo made by Purkinje about the time when Flourens first investigated the function of the semicircular canals.

Every one knows that if we stand up and turn round about a vertical axis and keep up this rotation for some time and then

stop, we see, or think we see, surrounding objects moving round. Purkinje studied the conditions under which this apparent rotation occurs, and arrived at the following conclusions, which have been confirmed by all succeeding observers:—1. That the direction of the apparent motion of surrounding objects depends upon the direction of the preceding real motion of our body, and is always opposite to it. 2. That the axis about which the apparent motion takes place is always that line in the head which was the axis of the preceding real rotation. Thus, if we turn round with our head bent forward so as to look straight down at the floor, and then stop, keeping the head in this position, the apparent rotation takes place about a vertical axis; but if, when we stop, we lift up our head and look forwards, the apparent rotation takes place about a fore and aft axis, the fore and aft axis having been vertical while the real rotation occurred. A trick, illustrating this principle, is sometimes played on persons ignorant of this law of giddiness. They are asked to take a poker in their hand, plant it vertically on the floor in front of them, bow down so as to touch the end of the poker with their forehead, and walk quickly three or four times round the poker, then rise up and walk to the door. The apparent rotation takes place about a fore and aft axis, because the fore and aft line in the head was the axis of the real rotation; they see objects rise up on the one side and fall down on the other; the floor seems to incline itself to one side, and equilibrium becomes impossible. This experiment may be varied in many ways: thus, instead of the forehead, one ear may be placed on the end of the poker; the rotation then takes place about a right and left axis—the line from ear to ear. On rising, apparent rotation occurs about this line as an axis, and the floor in front seems to slope up or down according to the direction of the original real rotation.

Purkinje explained these phenomena thus:—“During the rotation of the body about its longitudinal axis, the brain, in virtue of its soft consistence, ought to have a tendency to remain a little behind the movement of the walls of the skull. This is the same phenomenon which we observe in a liquid when the vessel containing it is set in rotation. The particles of the liquid preserve their position relative to the external space, until their adhesion to the walls of the vessel forces them to take part in the motion of the latter. The cohesion of the brain is too great to allow of the reproduction of the same phenomenon exactly; but as the brain is soft and capable, to a certain extent, of internal displacement, it has some of the properties of liquids. We must therefore admit that a movement more or less intense must produce a displacement and relaxation of its parts, although an actual rupture of continuity cannot occur. Such distortions should produce the same disturbances as actual mechanical lesions, and differ from them only in degree.”

This explanation is adhered to, in the main, by Dr. de Cyon, and although we do not admit that such tortional deformation of the brain is the chief or usual physical cause of the giddiness above described, it is probable that it has something to do with the phenomena when the rotation is very rapid and is suddenly stopped.

We now come to the modification of the theory of Goltz, which induced Dr. de Cyon to resume his experiments on the semicircular canals. This modification was made nearly at the same time by Prof. Mach, of Prague, Dr. Breuer, of Vienna, and Dr. Crum Brown, of Edinburgh. The papers in which they stated their views were written independently, and were published in the order above-mentioned within a period of about six weeks.

The views of the three observers are not quite identical, and it will be necessary to point out in what they differ; but they agree in so many details that a general description of their theory is possible. We have above called Goltz's theory *static*; in opposition to it we may call the Mach-Breuer-Brown theory *kinetic*.

Goltz regarded the semicircular canals as organs which, by difference of pressure in different parts of the system, give us a notion of the *aspect* of the head in space. Mach, Breuer, and Brown regard them as organs which, by virtue of the *inertia* of the contained liquid and movable soft parts, give us a notion of the *change of aspect* of the head.

The simplest form of this theory is that in which it is stated by Dr. Breuer:—

“In a system of three ring-shaped tubes, approximately at right angles to one another, and filled with liquid, as is the case in the semicircular canals, there are produced by every

rotational movement of the whole system (that is, of the head) currents of liquid in a direction opposite to that in which the head is turned. The amount of the flow in each canal depends upon the plane in which the head is turned and upon the rate of the rotation. There are perfectly fixed relations between the rotational movement of the head and the currents in the inclosed liquid; if these currents can be perceived they will give us an exact account of the rotational movement of the head. We may regard, as possible organs for the perception of the currents, the so-called 'auditory hairs' which project at right angles inwards from a widened and flattened part of the canal; they are thus placed so as to be most sensitive to currents in the canal, and are on the other hand connected to nerves, of which they form the end-organs.

"To turn these facts to account in the sense of Goltz's theory we must assume that every flow of the endolymph, perceived by the ampullary nerves, produces a sensation of rotation of the head in the plane of the canal in which the flow takes place, and in a direction opposite to it, but that the perceptions of the six ampullæ of the two labyrinths combine to form a joint sensation. . . .

"Our assumption has a necessary consequence. If the rotation of the head (of course along with the body) is kept up, the initial backward flow of the endolymph will be destroyed by friction against the walls. If the head then suddenly stops, the endolymph must, in virtue of its inertia, flow on in the sense of the rotation of the head; a sensation will therefore be produced of rotation of the head and body in a direction opposed to that of the previous rotation."

In this view the endolymph is held to lag behind the rotational movement of the head when this movement begins;—when the movement has continued at a uniform rate for some time, the endolymph is constrained, by fluid friction, to take part in the movement of the head, and if then the rotation of the head stops, the endolymph moves on. We have, thus, two ways in which a relative motion can occur between the endolymph and the walls of the cavity containing it:—1. When the head begins to move—here the walls leave the fluid behind. 2. When the head stops—here the fluid flows on. In both cases the sensation of rotation is felt. In the first this sensation corresponds to a real rotation, in the second it does not, but in both it corresponds to a real acceleration (positive or negative) of rotation, using the word acceleration in its technical kinematical sense.

Mach's view differs from Breuer's in this, that while Breuer assumes an actual flow of endolymph through the canals, Mach believes that the very narrow bore of the canals will preclude such a flow—the friction being so great that the most abrupt rotational movement of the head will not produce sufficient difference of pressure to cause an actual current. Instead of a current there will be produced a change of pressure in the ampulla, which would produce a current were the canal wider, and this change of pressure may be sufficient to act on the hair-cells, and irritate the ends of the nerves.

In Brown's statement of the theory, not the endolymph only, but the whole liquid and soft contents of the bony canals are supposed to lag behind the movement of the head, and in his first paper he suggested that there might be a relative motion between the bony and the membranous canals. This view, founded on the statement to be found in various anatomical text-books, that the membranous canals float nearly loose in the bony canals, is scarcely tenable when we know that the former are somewhat firmly attached at one side to the periosteum.

Another important point in which Brown's statement of the theory differs from that of Mach and from that of Breuer, lies in his regarding the two labyrinths as forming one organ, all the six canals of which are required to form a true conception of the rotatory motion of the head.

The doctrine of specific nervous action, now we believe generally accepted by physiologists, implies that while greater or less stimulation of an end-organ produces difference of sensation, a variety in the *mode* of stimulation cannot be perceived. Flow through the ampulla from the utricle to the canal on the one hand, and from the canal to the utricle on the other, must produce a precisely similar sensation if the hairs of the hair-cells are equally moved. We must therefore look further for an explanation of our power of distinguishing between rotation in the one sense and rotation in the other sense about the same axis.

Mach was at first inclined to suppose that in each ampulla there are two sets of nerves each sensible to rotation in one sense

only. He now adopts the explanation proposed by Brown, who based it upon the fact established by careful measurements in a considerable number of animals, that the *six* canals are sensibly parallel two and two. Thus the two horizontal canals are in the same plane, while the superior canal of one side is in a plane nearly parallel to that of the posterior canal of the other side. Further, in each of these three pairs (right and left horizontal, right superior and left posterior, right posterior and left superior), the two canals are so placed that when rotation takes place about the axis to which they are perpendicular, one of the two canals moves with its ampulla preceding the canal, so that the flow, or tendency to flow, is from ampulla to canal, while in the other the ampulla follows the canal and the flow, or tendency to flow, is from canal to ampulla. If, then, we suppose that flow from ampulla to canal—or, adopting Mach's view as stated above, *increase* of pressure in the ampulla—alone stimulates the hair-cells, while no effect is produced by flow in the opposite direction—or by *diminution* of pressure in the ampulla—we have in the six canals a mechanical system capable of giving us an accurate notion of the axis about which rotation of the head takes place, and of the sense of the rotation. To this explanation Dr. de Cyon objects that it assumes two organs, the superior canal of one side, and the posterior canal of the other side, which are not anatomically fellows, to be physiologically fellows. To this it is sufficient to answer that the motions which these two organs are supposed to perceive are produced by altogether different muscles. Let us take the case of the right superior and left posterior canal—the former is sensitive to rotation in one sense about an axis approximately passing through the left eye and the right mastoid process, a motion produced by muscles on the right side of the front of the neck, while the latter canal is sensitive to exactly the contrary motion about the same axis, and this motion is produced by muscles on the left side of the back of the neck. It is surely unreasonable to expect anatomical relations to exist between the organs perceiving two motions which do not exist between those producing them.

ALEX. CRUM BROWN

(To be continued.)

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

WE have already referred to the mathematical courses for session 1878-9 in Johns Hopkins University, Baltimore. The following is the detailed programme:—I. Prof. Sylvester will lecture on (a) determinants, (b) modern algebra, (c) theory of numbers. II. Dr. Story will lecture on (a) higher plane curves, (b) solid analytic geometry, (c) quaternions, (d) elliptic functions. III. Mr. Craig will lecture on hydrodynamics. IV. Lectures will be given by appointed instructors on (a) differential equations, (b) analytic mechanics, (c) conic sections, (d) theory of equations, (e) differential and integral calculus. V. Mathematical Seminarium.—A Mathematical Seminarium is conducted under the guidance of the Professor and Dr. Story; it comprises all the instructors and students of mathematics in the university. At its monthly meetings, besides occasional papers, such topics as may from time to time suggest themselves in the course of reading to the students or instructors, or may otherwise be of general interest to persons pursuing mathematical studies, are made the subject of free oral discussion. VI. Scientific Association:—The Scientific Association of the Johns Hopkins University meets once a month for the discussion of subjects of general scientific interest. At these meetings an opportunity is afforded for communicating abstracts of recent mathematical progress, as well as the results of individual research. VII. Mathematical Journal:—"The American Journal of Mathematics" is published quarterly in the City of Baltimore, under the auspices of the Johns Hopkins University, and affords an efficient medium of intercourse between members of the university engaged in original investigation, and a wide circle of mathematicians in America and in Europe. VIII. All the mathematical journals published at home and abroad are taken in by the university. At the Peabody Library complete sets of "Crelle's Journal" and the most important scientific transactions are also accessible. The university library and reading rooms are open daily from 9 A.M. to 10 P.M.

THE Calendar of the Yorkshire College for its fifth session, 1878-9, forms a volume of 140 pages. The college has now day classes in the following subjects:—Mathematics, experimental